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U.S. Dairy Forage Research Center 2000-2001 Research Report

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Appreciation is expressed to Peggy Carroll for her dedication to the task of typing and assembling this research summary.

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Preface

It is a pleasure to bring you these summaries of research conducted over the past two years at the U.S. Dairy Forage Research Center. The Center's mission is to build a knowledge and technology base for the dairy industry to fully exploit the use of forages in the production of milk. The Center was established in 1980 on the University of Wisconsin-Madison campus in Madison, WI, but is a federal unit of the Agricultural Research Service, U.S. Department of Agriculture (USDA). We employ agricultural engineers, plant and soil scientists, microbiologists, ruminant nutritionists, and a chemist who all work together to increase the efficiency of forage production and utilization by dairy farmers. At present, we have fifteen scientists: twelve at Madison, two cluster scientists at the University of Minnesota in St. Paul, MN, and one cluster scientist at Cornell University in Ithaca, NY. These scientists hold faculty appointments in university departments and provide supervision for approximately 6-8 graduate students and 4 postdoctoral fellows. We function in close cooperation with the agricultural experiment stations of several states.

The Center's 63-acre research farm is located in Prairie du Sac, WI and has facilities for housing and feeding 320 milking cows and 350 replacement heifers and dry cows. An additional 1,555 acres of adjacent land is utilized by the Center in agreement with the U.S. Department of the Army. In 1999, the U.S. Defense Department declared that the former Badger Army Ammunition Plant (BAAP), adjacent to our research farm, is excess property. The USDA has requested a no-cost transfer of custody of 1,718 acres of this excess federal land so that we can continue our research efforts. We are working with the Ho Chunk Nation, Wisconsin Department of Natural Resources, Sauk County, Sumpter and Merrimac Townships in Sauk County, the GSA, and the Army to develop a unified management strategy for the entire property to facilitate transfer of the land. We are encouraged by the cooperation of all parties to bring about a solution.

Regarding staff updates, we hired J. Mark Powell as a Soil Scientist/Agroecologist in December 2001. His expertise strengthens our integrated farming systems research effort. Mark earned degrees from the Clemson University, Cornell University, and Texas A&M University. He brings research experience with several international research organizations in which he developed an agroecology approach to ruminant livestock use of land bases to create economic alternatives with minimal ecologic impacts on land and soil resources. Check out the Enhanced Integrated Nutrient Management site on the DFRC web page, http://dfrc.ars.usda.gov/powell/ to see the immediate impact Mark brings to our research effort.

I am pleased to announce that Michael D. Casler, University of Wisconsin, has accepted our offer to fill the Research Geneticist position at USDFRC. Michael is no stranger to forage supporters, bringing 21 years of experience in forage breeding and genetics to the USDFRC effort. His contributions to improving forage grasses are recognized internationally. His efforts to improve cell wall digestibility of smooth bromegrass and perennial ryegrass, discover new varieties and improve management practices of perennial grasses for rotational grazers, as well as improvements in switch grass for biomass production, bring a unique expertise to dairy forage. He has the best skills to offer USDFRC using genetics and molecular genetics to develop new perennial grass and legume germplasm for dairy utilization, conservation uses, and value-added traits.

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Highlights of USDFRC 20th Anniversary Celebration – June 29 and 30, 2001
Neal Martin and Clive Holland

National recognition of research efforts of scientists, staff, and collaborators by citizens is the best accomplishment a group can receive. The U.S. Dairy Forage Research Center (USDFRC) Stakeholder Committee, chaired by Clive Holland, Pioneer Hi-Bred International, along with volunteers, private companies and staff, teamed together to tell citizens how our current research to increase utilization of forage crops by dairy cattle benefits communities. The theme "Cows, Crops and Communities" captured the importance of dairy forage research to a national audience.

The anniversary celebration occurred at 3 different venues: a recognition seminar for national media at the Fluno Center for Executive Education, University of Wisconsin-Madison; an open house at the USDFRC laboratory in Madison; and an open house at the research farm in Prairie du Sac.

Recognition Seminar

Over 14 national agricultural media representatives covered the seminar. The audience viewed a video tape from U.S. Senator Herb Kohl on the importance of dairy forage research, and heard a congratulatory letter from USDA Agriculture Secretary Anne Veneman, presented by USDA-ARS Administrator Floyd Horn. Dr. Horn and James Harsdorf, Secretary of Wisconsin Department Agriculture, Trade and Consumer Protection, also gave presentations. USDFRC scientists, along with industry representatives and farmers, completed the seminar with talks on the impacts of forage research. The video, presentations, and posters can be viewed in detail on the USDFRC web site: http://www.dfrc.ars.usda.gov/cd/StartHere.htm

Topics and speakers were: *U.S. Dairy Forage Research Achievements: Past, Present and Future*, Neal P. Martin, Center Director, USDFRC; Safe *Nutritious Milk from Improved Forage Crops,* Jim Hahn, Director, Membership & Procurement, Land O' Lakes, Arden Hills, MN; *Microbes Benefit Cows, Crops, and Communities, James* Russell, USDFRC Cluster Scientist (New York); *Improving Forage Crops is Good for Cows, Good for Communities*, Glen Broderick and Dave Mertens, Dairy Scientists, USDFRC; *Balancing Cows and Crops to Recycle Nutrients,* Michael Russelle, USDFRC Cluster Scientist (Minnesota); *New Crop Genetics Benefit Cows and Communities,* Mark McCaslin, Forage Genetics International, Savage, MN; *Dairy Farming in The West Needs Science of Cows and Crops to Improve Communities,* Steve Faber, Dairy Research Center, University of Arizona, Tucson, AZ; and *Importance of the USDFRC to the Upper Midwest Dairy Industry,* Dean Doornink - Jon-Dee Farm, Inc., Baldwin, WI.

Laboratory Open House

- The open house provided an opportunity for the public to better understand forages, dairy cattle, and the products generated from dairy cattle. Participants viewed displays and posters, a chef melted new cheese products to sample, and the Wisconsin Milk Marketing Board was on hand with a Volkswagon Beetle to promote Wisconsin dairy products.

Poster and display topics included:

- What is fiber, what is it made of, and how do dairy cows use it?
- Impact of increasing cell wall digestibility

- Cross-linking fiber limits digestion
- What is lignin?
- How forage samples are analyzed for structural studies
- Evolution of a new forage variety

- Forages for dairy production
- Breeding alfalfa with more digestible stems
- The rumen symbiosis: A partnership between the cow and its microbial population
- Molecular assessment of microbial populations in the rumen
- Inoculants-improving silage fermentation
- Bunker silo management
- Bag silos – Densities and losses
- Rapid forage analysis using NIRS
- Measuring fiber in feeds
- Responses of cows to differences in maturity and processing of corn silage
- Estimating nutritive value using a feed information expert system

- Reducing nonprotein nitrogen in alfalfa silage improves protein utilization
- Red clover silage as a replacement for alfalfa silage in dairy cow diets
- Rumen in vitro methods for testing the nutritional value of feeds
- Omasal sampling techniques for studying digestion in the rumen
- Milk urea concentration can be used to prevent overfeeding of protein
- Bacteriocins as an alternative to antibiotics
- New products from alfalfa
- Phosphorus requirements for lactating cows
- Roasted soybeans are an economical supplement for rumen undegraded (by-pass) protein
- Brown midrib corn silage for transition cows
- Grazing research at the U.S. Dairy Forage Research Center
- Integrated cropping systems and nutrient management on dairy farms
- Enhanced integrated nitrogen management on dairy farms
- Whole-farm phosphorous management on dairy farms
- Tannin-containing forage crops: A way to improve nitrogen use and profitability on dairy farms?
- Well-managed grazing helps protect ground water quality

Research Farm Open House

Various displays were set up (see below), and USDFRC scientists were available to answer questions. James Harsdorf, Wisconsin Secretary of Agriculture, Trade and Consumer Protection, spoke briefly on the value of the USDFRC to dairy farmers. After Secretary Harsdorf's presentation, Sheri Hicken, Wisconsin's 2001 Alice in Dairyland, addressed the audience.

Station 1: **Demonstration of Sampling the Ruminant Digestive Tract**
Reducing Nonprotein Nitrogen in Alfalfa Silage Improves Protein Utilization
Red Clover Silage as a Replacement for Alfalfa Silage in Dairy Cow Diets
Rumen In Vitro 'in Glass' Methods for Testing the Nutritional Value of Feeds

Station 2: **Integrated Cropping Systems and Nutrient Management of Dairy Farms**
Whole-Farm Phosphorus Management on Dairy Farms
Well-Managed Grazing Helps Protect Ground Water Quality
Tannin-Containing Forage Crops: A Way to Improve Nitrogen Use and Profitability of Dairy Farms
Enhanced Integrated Nitrogen Management on Dairy Farms
Russelle's Believe It or Not — Roots on Display

Station 3: **Learn How Improving Digestion of Cell Walls Enhances Animal Health and Milk Production**

Station 4: **New Uses for Alfalfa**
Breeding Alfalfa with More Digestible Stems

Station 5: **How New Forage Varieties are Developed**

Station 6: **Improving Silage Making and Storage**
Inoculants – Improving Silage Fermentation
Bunker Silo Management
Bag Silos – Densities and Losses

Station 7: **Feeding of Dairy Cattle**
Roasted Soybeans as an Economical Supplement for Rumen Undegraded (Bypass) Protein
Reducing Dietary Phosphorus to Lower Costs and to Improve the Environment
Responses on Performance and In Vivo Digestibility of High- and Low-Producing Cows To Maturity and Processing of Corn Silage.

History of the U.S. Dairy Forage Research Center

Congress and the United States Department of Agriculture/Agricultural Research Service (USDA-ARS) established the U.S. Dairy Forage Research Center (USDFRC) in 1978 with the mission to develop and disseminate knowledge and tools needed for enhancing sustainable and competitive dairy forage systems that are in harmony with the environment, promote animal health, and ensure a safe and healthy food supply.

USDFRC consists of a federally owned laboratory located on the University of Wisconsin-Madison campus and a federally owned support research farm (65 acres with buildings owned by USDA and 1400 acres leased from the Department of Army) located near Prairie du Sac, WI that includes a 320-cow research dairy herd.

Although USDFRC was first envisioned as a regional laboratory, the program quickly and clearly developed a national scope. About half of the Center's resources are used to support basic or fundamental research that has no geographical boundaries. The other half of the resources are used to support more applied research, and over half of this amount can be considered applicable to all of North America and to many locations around the world.

A crucial feature in the development of USDFRC has been the concept of central facilities at the University of Wisconsin, and cluster scientists located at several other universities. This concept has provided for a stronger scientific program and greater cooperation with other researchers, as well as widespread support from the industry and enhancement of the overall forage research program. USDFRC cluster scientists are now located at the University of Minnesota, St. Paul, MN, and at Cornell University, Ithaca, NY.

Research Overview

Research by the Center's thirteen scientists in Wisconsin plus the three cluster scientists focuses on important national questions and problems associated with forage and its relationship with other feedstuffs for the dairy industry and nutritional requirements of the ruminant, primarily the dairy animal.

ARS uniquely designs the scientific efforts at the Center such that research conducted at the laboratory is conducted with a multi-discipline approach. Disciplines represented at the Center laboratory are:
plant genetics, plant physiology, chemistry, rumen microbiology, soil science, agricultural engineering, agronomy, ruminant nutrition, and dairy science.

Research Accomplishments

Between 1980 to 1998, milk production in the United States increased 22%, while the number of cows declined by 15% and the total number of dairy farm operations dropped by 65%. Annual milk production per cow increased 45%, from 11,875 to 17,189 lbs. Dairy farm enterprises across the country generated almost $21 billion in cash farm receipts from milk sales. Factors that have contributed to this incredible increase are improvements in forage and feed consumption. Dairy cattle consume 100 million tons of forage each year valued at about $8 billion.

Research conducted at the U.S. Dairy Forage Research Center (USDFRC) on forage production, harvest, storage, and feeding forage quality has contributed to the dynamic changes in the dairy industry. The work of USDFRC has also advanced our understanding of the important role of forage crop quality to improve cow performance.

IMPROVEMENTS IN FORAGE-BASED RATIONS

The rumen sub model was developed for the Cornell Net Carbohydrate and Protein System, a method of feed formulation used by some dairy producers and nutritionists, and adopted at Level 2 by the National Research Council Beef Committee. Use of this model can result in feed savings as much as 17%.

- The NDF-Energy Intake System was developed as a way of directly using neutral detergent fiber (NDF) to formulate dairy rations that maximize forage use while promoting maximum milk production. The model is used to predict the intake portion of the Relative Feed Value Index, a quality index used to market cool-season legumes, grasses, and legume-grass mixtures nationally and internationally since 1990.

- The concept of physically effective NDF was created, combining the chemical and physical properties of fiber into a measurement used to meet the minimum fiber requirement of cows. The concept has been incorporated into several ration formulation software programs.
- Optimum conditions for roasting of soybeans to enhance bypass protein value were identified. This work has greatly contributed to widespread adoption of roasted soybeans in dairy cow diets and the generation of $20 to $40 million annually in added value.
- Improved digestibility of the vegetative part of the corn plant was demonstrated for brown midrib varieties or by cutting silage corn higher (20-28" vs. 8-10"), thus leaving some of the poorly digested stalk in the field. These improvements can increase milk production by 2-4 lbs per cow/day, and this increase more than pays for the loss of yield (or higher costs) associated with growing brown midrib varieties, or cutting silage corn at higher levels.
- The relative value was determined for various feed proteins used as supplements for lactating dairy cows fed alfalfa silages as their principal forage.
- A previously unrecognized group of ammonia-producing rumen bacteria were isolated and identified and shown to be sensitive to the ionophore, monensin. This group of bacteria wastes approximately $1 billion per year in protein.
- A sterilized, natural preparation of ruminal microorganisms was developed that can decrease calf diarrhea fivefold and nearly double the calf's rate of weight gain early in growth.

FORAGE DIGESTIBILITY

- The most comprehensive characterization of lignin structure and phenolic-carbohydrate cross-linking was completed. This information has dramatically altered scientists' views of cell wall structure and has identified routes to genetic improvement of forages for enhanced digestibility that are being pursued by several agricultural biotechnology companies. Some of these companies have established Cooperative Research and Development Agreements with USDFRC to further carry out this work.
- Pectin in alfalfa displayed rates of ruminal digestion equivalent to those of cereal starches. It produces a favorable fermentation product mix that maintains the level of butterfat in the milk. This work has stimulated breeding efforts by several companies, aimed at increasing pectin content of alfalfa.
- The anatomical features of forage corn that have greatest influence on its digestibility were identified. This information has provided breeders with a selection tool to develop varieties that have improved digestibility.
- Equations were developed that relate fiber particle surface area and ruminal pH to the rates of digestion of cellulose (the major component of forages). These equations will be useful in refining models of ruminal fiber digestion.

FORAGE AND FEED ANALYSIS

- The method used to analyze neutral detergent fiber (NDF), an important component for balancing dairy cattle rations, was improved. The modified NDF method has been adopted by the National Forage Testing Association (NFTA) to test the proficiency of at least 150 forage testing laboratories in the U.S. that analyze millions of forage samples each year for farmers, nutritional consultants, and feed industry representatives.
- Methods to quantify and characterize lignin in forages were developed and are now being used by researchers worldwide.

- Methods to measure how rapidly feed components are digested, based on production of fermentation gases, were improved and extended to soluble sugars in forages. This is the most difficult component for which to obtain accurate digestion rate data. The method has been used to identify new germplasm that have enhanced rates of carbohydrate digestion.
- A laboratory method was developed to rapidly determine rumen undegradable protein. This procedure is useful as a tool to optimize pretreatments to enhance the amount of bypass protein in a feed.
- Procedures have been developed to detect and eliminate non-random biases in forage composition estimated by Near Infrared Reflectance Spectroscopy (NIRS), a rapid analytical method widely used by forage testing labs. The methods have been used to improve protocols for selecting and evaluating calibration equations that underlie the use of NIRS technology.

FORAGE PRODUCTION AND MANAGEMENT

- Two varieties of red clover, Arlington and Marathon, were developed and released. The varieties have increased persistence, longevity, yields, and disease resistance, and annually save $140/acre/year on at least 250,000 acres in the Midwest.
- The first tetraploid and triploid red clover germplasm lines were developed. These varieties will be useful as genetic tools for development of new red clover varieties.
- Improved varieties of birdsfoot trefoil and kura clover were developed and released.
- A computerized DAiry FOrage SYstem Model (DAFOSYM) was developed that simulates growth, harvest, storage, feeding, and use of alfalfa and corn in dairy operations. The model has been distributed to end-users for use as a decision aid.
- The most comprehensive model to date was developed to predict and control aerobic deterioration of silages at the silo face during unloading.
- The first predictive tool was developed that allows farmers to assess the most effective means of increasing silage density to resist dry matter losses during ensiling.
- Drying rates, losses, and other performance measures of various types of forage harvesting methods were quantified. Application of this research provides the best management practice for harvesting hay, potentially saving 15% in field losses. If applied to 40% of the U.S. hay crop, the potential savings could top $4.4 million per year.
- Technology for farm-scale chemical conditioning of alfalfa was developed and transferred to end-users, returning $2 per dollar invested. If the technology is applied to just 25% of the U.S. alfalfa hay crop, it could yield a return of $1.6 million.

ADDING VALUE TO FORAGE OPERATIONS

- A novel field macerator machine was designed, built, and demonstrated. Manufacturing a field macerator to replace current mower-conditioners can potentially reduce drying time of alfalfa hay by two days, with increased dry matter digestibility and improved protein utilization.
- Conjugated linoleic acid (CLA), a natural anti-cancer agent produced in ruminants, was shown to be three- to fivefold higher in the milk of grazing cows than in cows fed conserved forages. In addition, the CLA content of milk from cows fed conserved forages increased to the levels found in the milk from grazing cows by feeding unsaturated vegetable oils, such as soybean oil.
- A simple method was developed to identify conditions under which use of silage inoculants yields an economic benefit. This information was distributed to farmers and extension agents.

- Technology was developed for wet-fractionation of alfalfa to produce a high-protein food for use in developing countries. A fiber residue suitable for fermentation to a variety of products was also developed. Simultaneous saccharification and fermentation (SSF) of alfalfa fiber produced during wet fractionation has been shown to make lactic acid at yields of up to 60% of fiber dry matter.
- The feasibility of using alfalfa stems as a biofuel was demonstrated. This cooperative research with the University of Minnesota paved the way for formation of the Minnesota Valley Alfalfa Producers, a farmer cooperative for production and dry fractionation of alfalfa to produce alfalfa stem fuel and alfalfa leaf protein meal.
- Collaborative work with the University of Wisconsin resulted in the development of transgenic alfalfa that produces Phytase, an enzyme lacking in the digestive tracts of swine and chickens. Feeding trials have revealed that this alfalfa serves as an effective feed, and the capacity of the enzyme to degrade phytic acids in feeds eliminates the need for phosphorus supplementation in the diet.
- Collaborative work with the U.S. Forest Products Laboratory (Forest Service-USDA) demonstrated the utility of woven mats of alfalfa fiber to remove heavy metals from wastewater and storm water runoff.
- Collaborative work with the U.S. Forest Products Laboratory also demonstrated the potential use of rumen bacteria for fermentation of forage fiber to biological adhesives. These adhesives may be used to partially replace environmentally unfriendly phenol-formaldehyde resins currently used in the forest products industry.

FORAGES AND THE ENVIRONMENT

- Reduction of phosphorus in mixed forage/concentrate diets by 20% from current NRC recommendations resulted in a 25-30% reduction in phosphorus excretion by the cow, and a potential savings to dairy producers of ~$100 million annually.
- Inexpensive addition of sodium carbonate to cow manure effectively reduced populations of *E. coli* in the manure.
- Practical use of deep-rooting varieties of alfalfa to remove nitrate from soils was demonstrated in soil contaminated by nitrogen from a railroad tank car derailment.

INFORMATION TRANSFER

- Hosted International Symposium on Forage Cell Wall Structure and Digestibility, October 7-10, 1991. One hundred sixty-five people representing 15 countries attended. ASA, CSA, and SSSA Monograph: "Forage Cell Wall Structure and Digestibility," Eds: H.G. Jung, D.R. Buxton, R.D. Hatfield, and J. Ralph, 794 pages, 1993. Now in second printing.
- Hosted Research Industry Conference in 1996. Fifteen scientists addressed the state of dairy forage research in 118-page proceedings.
- Hosted 15th *Trifolium* Conference, June 12-13, 1998.
- Published more than 1,000 publications (1000th publication published in November 1999).
- Distributed 16 annual research summaries to 700 extension and industry product specialists, farm advisors, and farmers that outlined the impact of research in 785 different short topics totaling 1,668 pages.
- Hosted many state and region farm field days

INTERNATIONAL COLLABORATION

Work at USNDFRC has created interest far beyond the borders of the United States. USDFRC scientists have collaborated with these foreign research institutes and universities:

AgResearch, New Zealand
Agriculture Canada, Quebec
Agriculture Canada, Nova Scotia
Danish Institute of Animal Science, Tjele
IMAG, Wageningen, The Netherlands
INRA, Reims, France
INRA, Paris, France
Institute of Wood Research, Japan
Kangweon University, Korea
Teagasc, Grange Research Centre, Ireland
Universite Paul Sabatier
University of Groningen, The Netherlands
University of Stuttgart Hohenheim, Germany
Volcani Center, Bet Dagan, Israel
Agricultural Research Institute, Norway
Agriculture Canada, PEI
CSIRO, Australia
ID-DLO, Lelystad, The Netherlands
INIA, Uruguay
INRA, Clermont-Ferrand, France
Institute of Food Research, Norwich, UK
INTA, Argentina
Swedish University of Agricultural Sciences
The Rowett Institute, Aberdeen, Scotland
University of Australia
University of Brisbane, Australia
University of Kiel, Germany
Wageningen Agricultural Univ., The Netherlands